Spatial Agglomeration of Heavily Polluting Industries in China and Its Environmental Effects: Characteristics and Implications (Postprint)

Authors: Chen Hongyang, Yu Jianhui, Zhang Wenzhong

Date: 2024-03-27T00:00:00+00:00

Abstract

Heavy pollution industries constitute a significant source of industrial pollutants. Understanding the spatial agglomeration characteristics, influencing factors, agglomeration mechanisms, and environmental effects of heavy pollution industries in China can facilitate the identification of potential pollution risk areas to address increasingly severe environmental pollution challenges. This article systematically examines China' s industrial economic data from 1999 to 2021, characterizing the spatial distribution and agglomeration patterns of heavy pollution industries. The findings reveal that: (1) Shandong, Jiangsu, Zhejiang, and Guangdong have been high-output regions for heavy pollution industry development over the past two decades, while Xinjiang, Inner Mongolia, Shanxi, Shaanxi, Henan, and Sichuan represent potential regions for future agglomeration of heavy pollution industries; (2) Production costs (factor endowments), environmental regulation, economic development level, market share, and industrial structure are key determinants of heavy pollution industry development, with a significant inverted-U relationship existing between labor costs and heavy pollution industry development; (3) Regional heterogeneity characterizes heavy pollution industry development, with a pronounced pollution haven effect in eastern regions, while central and western regions exhibit more explicit location orientation toward areas with low labor costs and abundant resources; (4) Agglomeration of heavy pollution industries significantly increases industrial pollutant emissions, with a significant inverted-U relationship between heavy pollution industry agglomeration and environmental pollution, while environmental regulation has not effectively played its role in pollution reduction and emission control. Based on these findings, the article further proposes mitigation measures and policy recommendations for various regions to address heavy pollution industry agglomeration and reduce potential pollution risks, aiming to provide references for achieving the goals of Beautiful China construction.

Full Text

Preamble

Citation Format: Chen Hongyang, Yu Jianhui, Zhang Wenzhong. Spatial agglomeration and environmental effects of heavy polluting industries in China: Characteristics and enlightenment. *Bulletin of Chinese Academy of Sciences*, 2023, 38(12): 1939-1949, doi: 10.16418/j.issn.1000-3045.20231006002.

CHEN Hongyang, YU Jianhui*, ZHANG Wenzhong**

CAS Key Laboratory of Regional Sustainable Development Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

Abstract

Heavy polluting industries constitute a major source of industrial pollutants. Understanding the spatial agglomeration characteristics, influencing factors, agglomeration mechanisms, and environmental effects of China' s heavy polluting industries is essential for identifying potential pollution risk areas and addressing increasingly severe environmental challenges. This study systematically examines China' s industrial economic data from 1999 to 2021 to characterize the spatial distribution and agglomeration patterns of heavy polluting industries. The findings reveal four key insights: (1) Shandong, Jiangsu, Zhejiang, and Guangdong have been high-output regions for heavy polluting industries over the past two decades, while Xinjiang, Inner Mongolia, Shanxi, Shaanxi, Henan, and Sichuan represent potential future agglomeration areas; (2) Production costs (factor endowments), environmental regulation, economic development level, market share, and industrial structure are critical determinants of heavy polluting industry development, with a clear inverted U-shaped relationship between labor costs and heavy polluting industry growth; (3) Regional heterogeneity is evident, with the eastern region exhibiting a significant "pollution haven" effect, while central and western regions demonstrate stronger orientation toward low labor costs and resource-rich locations; and (4) Agglomeration of heavy polluting industries significantly increases industrial pollutant emissions, showing a clear inverted U-shaped relationship with environmental pollution, yet environmental regulations have not effectively reduced pollution or emissions. Based on these findings, the paper proposes targeted mitigation measures and policy recommendations for addressing heavy polluting industry agglomeration and reducing potential pollution risks, offering valuable insights for achieving the Beautiful China initiative.

Keywords: heavy polluting industry, agglomeration, pollution haven hypothesis, environmental regulation, environmental effect

1. Heavy Polluting Industries and Environmental Effects: Analytical Framework

Environmental pollution has long been a critical concern for national economic development and reform innovation. Industrial pollutants constitute a significant component of pollution emissions, with heavy polluting industries serving as the primary source of industrial pollutant discharge and imposing substantial negative externalities on ecological systems. Therefore, examining the environmental effects of industrial agglomeration from the perspective of heavy polluting industries is crucial. Industries exhibit cross-regional spatial migration behavior, essentially seeking optimal production locations. As production costs rise, profit-maximizing firms continuously relocate to adapt to increasingly complex market conditions. Industries that impose severe negative environmental externalities are particularly sensitive to environmental policies and more likely to trigger industrial transfers in response to policy changes. Typically, economically developed countries or regions transfer such industries to relatively less developed areas through production, investment, and trade. Strictly speaking, pollution-intensive industry transfer occurs both internationally and domestically, with existing evidence indicating that some pollution-intensive industries in China are shifting toward central and western regions. While receiving these industries, host regions must also bear the negative environmental externalities brought by industrial transfer, making the spatial agglomeration of heavy polluting industries a key factor reshaping the spatial layout of industrial pollutants and influencing regional environmental policies. Understanding the influencing factors and driving mechanisms of heavy polluting industry transfer is therefore essential for correctly interpreting ongoing international and domestic industrial shifts, adjusting regional ecological and environmental protection policies (particularly in central and western regions), and realizing the sustainable development vision of a Beautiful China.

Academic analysis of the environmental effects of industrial transfer is relatively mature, with discussions focusing primarily on empirical tests of the "pollution haven" hypothesis and the Environmental Kuznets Curve. International research concentrates on national and industrial scales, while domestic studies focus primarily on provincial and municipal levels, leaving room for further improvement at the industrial level. Although substantial research achievements have been made on the agglomeration of pollution-intensive enterprises and their environmental effects, identifying heavy polluting industry agglomeration and its environmental effects from a macro perspective remains important. This is crucial for analyzing industrial agglomeration and transfer issues at the macro scale, understanding firm relocation preferences and environmental pollution issues in host regions at the micro scale. Against the backdrop of constrained resource development, tightened environmental protection policies, and slowing economic growth, scientifically planning the transfer trends of heavy polluting industries and clarifying their spatial agglomeration characteristics hold significant meaning for adjusting major productivity layouts, comprehensively

delineating regional functional zones, enhancing ecosystem values across regions, and achieving strategic spatial deployment aligned with national objectives and high-quality development across all territories. This research focuses on three aspects: (1) identifying the spatial distribution and agglomeration characteristics of China' s heavy polluting industries over the past two decades; (2) analyzing the main factors driving heavy polluting industry agglomeration, including whether production costs (factor endowments), environmental regulation, and foreign direct investment have promoted agglomeration in central and western regions; and (3) examining pollutant emission transfers during the relocation process of heavy polluting industries and assessing whether environmental pollution problems derived from future transfers will continue to worsen.

1.1 Heavy Polluting Industry Dataset

This study collected China's industrial economic data from 1999 to 2021, sourced from the *China Industrial Economic Statistical Yearbook*. The industrial economic data covers various industry types detailed in Supplementary Table 1 and Supplementary Table 2 . Missing data for the extractive industries and electricity, heat, gas, and water production and supply sectors in 2004, as well as industrial economic data for 2017, were supplemented using mean value imputation.

Currently, there is no strictly defined classification for heavy polluting industries, though most scholars follow environmental protection standards issued by government departments. The *Environmental Information Disclosure Guidelines for Listed Companies* issued by the Ministry of Ecology and Environment indicates that heavy polluting industries primarily involve thermal power, steel, cement, electrolytic aluminum, coal, metallurgy, chemical, petrochemical, building materials, papermaking, brewing, pharmaceuticals, fermentation, textiles, leather, and mining. This study references the *Industry Classification Management Catalogue for Environmental Verification of Listed Companies* (issued by the former Ministry of Environmental Protection as Document No. 373 [2008]) to define heavy polluting industries within the industrial sector (see Supplementary Tables 1 and 2).

1.2 Environmental Pollution Dataset

Heavy polluting emissions are categorized by source into wastewater, waste gas, and industrial solid waste. Considering data continuity and consistency, this study uses partial data as alternative variables for robustness checks to enhance the reliability of empirical results. Data for wastewater, waste gas, and solid waste are sourced from the *China Statistical Yearbook* and *China Environmental Statistical Yearbook*. Data for environmental regulation, economic development level, market share, industrial structure, and factor costs are sourced from the *China Statistical Yearbook*. Technological innovation data (focusing on R&D expenditure) is sourced from the *National Statistical Bulletin on Science and*

Technology Expenditure published by the National Bureau of Statistics. Data descriptions and descriptive statistics are provided in Supplementary Table 3 .

2. Empirical Analysis of Heavy Polluting Enterprises in China

2.1 Agglomeration Characteristics of Heavy Polluting Industries

By mapping the spatial distribution of total output value of heavy polluting industries in China for the years 1999, 2003, 2007, 2011, 2015, and 2021 (Figure 1 [Figure 1: see original paper]), we observe a clear diffusion trend from east to west and from coastal to inland regions. The overall spatial hierarchy is distinct, with coastal provinces, central regions, and northwest inland areas showing staggered characteristics. Shandong, Jiangsu, Zhejiang, and Guangdong have consistently been agglomeration highlands for heavy polluting industries, while Xinjiang, Inner Mongolia, Shanxi, Shaanxi, Henan, and Sichuan demonstrate significant growth momentum and represent potential new agglomeration areas for future heavy polluting industries.

From the spatial distribution maps of provincial heavy polluting industries from 1999 to 2021, we can trace their development, transfer, and diffusion trends over the past two decades. In 1999, coastal provinces showed significantly higher output values than other regions. By 2007, Shandong, Jiangsu, and Guangdong had become clearly identifiable heavy polluting industry agglomeration areas. Subsequently, heavy polluting enterprises gradually diffused toward Zhejiang, Liaoning, Hebei, and Henan. During this period, these regions became new agglomeration highlands while heavy polluting industries further spread to central regions including Shanxi, Hubei, Anhui, and Jiangxi. After 2015, Shaanxi, Gansu, Chongqing, Guizhou, and Yunnan emerged as host regions and potential development zones for heavy polluting industry transfer. By the end of 2021, heavy polluting industries in Xinjiang and Inner Mongolia had rapidly expanded, with output values in Sichuan, Shanxi, Hubei, and Anhui also continuously increasing. Overall, heavy polluting industry development in Northeast China has lagged behind, likely related to the region' s development history and relevant policies.

2.2 Influencing Factors and Mechanisms of Heavy Polluting Industry Agglomeration

2.2.1 Influencing Factors This study posits that agglomeration of heavy polluting industries results from industrial transfer and industrialization processes. The domestic transfer of heavy polluting industries essentially represents changes in location selection within China, where firms must consider factor costs and regional acceptance policies. Due to their environmental impact, location choices for heavy polluting industries typically involve consideration of local environmental policies. The "pollution haven"hypothesis suggests that pollution-intensive industries tend to transfer to countries or regions with relatively lower

environmental standards (environmental regulation). This hypothesis has certain preconditions, including free trade, the law of one price, and differences only in environmental regulation between countries or regions. Although trade barriers and transportation costs exist in reality, (risk-free) arbitrage mechanisms between countries or regions ensure that actual price levels generally conform to the law of one price. When product prices are clear, production costs (factor endowments) affect production locations and thus influence the direction and destination of industrial transfer. When other conditions are essentially identical, regions with lower environmental standards (environmental regulation) become primary destinations for pollution-intensive industry transfer.

Therefore, this study focuses on the effects of production costs (factor endowments), environmental regulation, and foreign direct investment on heavy polluting industry agglomeration as core explanatory variables, while controlling for economic development level, market share, industrial structure, and technological innovation. To test whether the Environmental Kuznets Curve holds at the provincial level, we include the squared term of economic development level in our model.

Our analysis yields several key findings: (1) **Production cost (factor endowment) factors** exhibit the strongest influence on heavy polluting industry agglomeration among core explanatory variables. Heavy polluting industries are dominated by mining, smelting, and processing of mineral resources such as coal, petroleum, and metals. These resource-oriented heavy polluting industries feature high wages due to compensating wage differentials, potentially creating synchronization between high labor costs and heavy polluting industry presence. While preferred host regions for heavy polluting industries offer advantages such as labor abundance and low production costs, relocating firms also comprehensively evaluate factors including local economic development level, transportation infrastructure, and supporting policies. Only when these conditions reach certain thresholds do wage levels become a primary consideration, meaning labor costs in some host regions do not necessarily hold overwhelming advantages among alternative locations.

(2) **Environmental regulation factors** are not significant when individual effects are fixed but show positive correlation with industrial agglomeration when time effects are fixed. The "pollution haven" effect at the provincial level is not significant over long time scales, providing limited support for the "pollution haven" hypothesis. As local governments increasingly prioritize ecological protection and environmental enforcement, regional disparities in environmental policies gradually diminish, rendering the strategy of seeking lower environmental regulation less effective for heavy polluting industries.

(3) **Foreign direct investment factors** do not significantly affect heavy polluting industry agglomeration, indicating that heavy polluting industry transfer primarily occurs at the inter-provincial scale rather than through international channels.

(4) **Economic development level, market share, and industrial structure factors** exert highly significant effects on heavy polluting industry agglomeration, consistent with traditional industrial location theory and mainstream views in industrial and regional economics.

(5) **Technological innovation factors** are significant only when time effects are fixed, suggesting a positive correlation between long-term R&D investment and heavy polluting industry agglomeration. This relationship is inseparable from potential industrial transformation and upgrading, reflecting a shift in technology investment toward heavy polluting industries, possibly related to improved extraction technologies, industrial chain upgrading, and even environmental protection investment in resource-based regions.

2.2.2 Agglomeration Mechanism The impact of heavy polluting industry agglomeration on local environmental pollution—that is, whether such agglomeration causes significant pollution in host regions—is examined through two core variables: heavy polluting industry agglomeration and environmental regulation.

Core Variables: (1) Heavy polluting industries significantly increase pollutant emissions. A non-linear relationship exists between heavy polluting industries and environmental pollution, with inverted U-shaped relationships observed between industrial agglomeration and total industrial waste gas emissions and industrial solid waste generation. Pollutant emissions initially rise then decline as heavy polluting industry agglomeration intensifies.

(2) Environmental regulation has not yet played an effective role in reducing pollution and emissions at the provincial level. Environmental regulation shows significant positive correlation with total industrial wastewater discharge, total industrial waste gas emissions, and industrial solid waste generation. Future efforts require continued deepening of environmental protection policies and ecological governance concepts to enhance environmental enforcement strength.

Other Factors: (1) **Technological innovation** has played a role in reducing pollutant emissions. Adoption of cleaner, more efficient, and sustainable emission reduction technologies can effectively decrease total industrial wastewater discharge and industrial solid waste generation from heavy polluting industries.

(2) **Foreign direct investment** is significant only in reducing industrial solid waste generation from heavy polluting industries, suggesting that foreign enterprises may have introduced more environmentally friendly concepts and advanced technologies to waste-emitting industries.

(3) **Regional economic development level** shows significant positive correlation with pollutant emissions. As per capita GDP increases, pollutant emissions gradually rise, consistent with basic environmental economics

theory.

(4) **Market share** (specifically, total GDP) exhibits negative correlation with pollutant emissions (except for industrial wastewater discharge). This is because market share correlates with economic structure—regions with higher GDP totals have more developed service sectors and larger tertiary industry shares, a result that mutually corroborates with the coefficient of the industrial structure variable.

(5) **Industrial structure** shows significant positive correlation with pollutant emissions. Pollutant emissions are typically associated with industrial activities; higher output value in the secondary industry leads to greater pollutant emissions, making the industrial structure variable (total secondary industry output value) significantly positively correlated with pollutant emissions.

2.3 Regional Heterogeneity

Labor costs and regional robustness tests reveal the driving mechanisms and regional heterogeneity in China' s heavy polluting industry development. Nonlinear relationship tests for production costs (factor endowments) show an inverted U-shaped relationship between labor costs and heavy polluting industry development in China. Influenced by industry types and compensating wage differentials, heavy polluting industry development has increased labor costs in host regions, yet excessively high labor costs further promote heavy polluting industry transfer. Regional heterogeneity reveals the gradient characteristics of heavy polluting industry transfer within China: the eastern region serves as the primary destination for international heavy polluting industries, which seek lower labor costs, making the eastern region a "pollution haven" for international heavy polluting industry transfer. Central regions show more pronounced orientation toward low labor costs and resource-rich locations. The inverted U-shaped relationship between labor costs and heavy polluting industry development is significant in western regions. Northeast China' s heavy polluting industries are more influenced by their own industrial base and international industrial transfer, developing at a relatively slow pace.

3. Main Conclusions

This study systematically examines the agglomeration and spatial distribution of China' s heavy polluting industries over the past two decades, analyzes influencing factors and agglomeration mechanisms using panel data fixed-effects models, and investigates the environmental effects of heavy polluting industry agglomeration. Four main conclusions are drawn:

(1) The agglomeration characteristics of heavy polluting industries align with overall international and domestic industrial transfer trends, showing a clear diffusion pattern from east to west and from coastal to inland regions. Shandong, Jiangsu, Zhejiang, and Guangdong have been regions with high

agglomeration levels of heavy polluting industries over the past 20 years, while Xinjiang, Inner Mongolia, Shanxi, Shaanxi, Henan, and Sichuan represent potential future agglomeration areas.

(2) Fixed-effects model results indicate that factor endowments, environmental regulation, economic development level, market share, and industrial structure are key factors affecting heavy polluting industry development. Production costs (factor endowments) show positive correlation with heavy polluting industry development. Model results provide limited support for the "pollution haven" hypothesis at the national provincial scale. Technological innovation, significant only in the long-term time scale, may reveal a shift in technology investment that has promoted industrial upgrading and transformation in China' s heavy polluting industries.

(3) Labor costs and regional robustness tests reveal the driving mechanisms and regional heterogeneity of China' s heavy polluting industry development. Non-linear relationship tests show an inverted U-shaped relationship between labor costs and heavy polluting industry development. Regional heterogeneity analysis reveals significant "pollution haven" effects in eastern regions, while central and western regions show stronger orientation toward low labor costs and resource-rich locations.

(4) The environmental effects of heavy polluting industry agglomeration are significant, with such agglomeration substantially increasing industrial wastewater, waste gas, and solid waste emissions. Although an inverted U-shaped relationship exists between heavy polluting industry agglomeration and environmental pollution, this study' s results cannot support the conclusion that environmental regulation reduces pollutant emissions. More importantly, the Environmental Kuznets Curve does not hold at China' s provincial scale, with many provinces not yet reaching the pollution inflection point.

4. Research Implications

Based on empirical analysis of influencing factors and environmental effects of heavy polluting industry agglomeration, this study offers the following insights for adjusting heavy polluting industry layouts and formulating environmental regulations and protection policies in China:

(1) **Spatial concentration of economic activities facilitates pollution reduction.** Local governments should accommodate the agglomeration trend of heavy polluting industries by reserving and planning industrial parks with supporting infrastructure. Concentrated layout of heavy polluting industry clusters can enhance spatial agglomeration and reduce ecological and environmental pollution.

(2) **Different policy orientations should be formulated when guiding**

and hosting heavy polluting industry development.

- **Eastern regions** should focus on unified planning at the regional scale, simultaneously raising environmental policy thresholds and strengthening regional control over pollutant emissions from heavy polluting industries to reduce "pollution haven" effects. This approach will promote orderly pollution reduction across the eastern region and establish it as a model area for Beautiful China construction.
- **Central and western regions** should leverage their distinctive advantages by fully utilizing low-cost benefits to scientifically introduce relevant heavy polluting industries within their resource and environmental carrying capacities. These regions should build high-quality heavy polluting industry clusters, guide rational industrial layout, and promote transformation and technological upgrading during the relocation process. Simultaneously, they must urgently improve supervision mechanisms before, during, and after heavy polluting industry introduction to avoid the "pollute first, treat later" path.
- **Northeast China** should strengthen transformation and upgrading of heavy polluting industries, enhance industrial competitiveness, and fully exploit existing industrial foundations to achieve regional revitalization through industrial upgrading and renovation.

(3) **Ecological protection in ecologically fragile areas requires greater attention with proactive policy avoidance schemes to reduce environmental pressure from heavy polluting industry development.** Governments should address the more severe environmental pollution problems arising from heavy polluting industry transfer to ecologically fragile regions such as Xinjiang and Inner Mongolia. More forward-looking macro-control policies are needed to address potential environmental risks. In summary, all regions should adopt targeted industrial guidance and pollution response strategies tailored to local conditions, striving to minimize environmental pollution while developing industries and revitalizing economies, collectively working toward building a Beautiful China.

References

1. Zhao J J, Ru L F, Duan X W, et al. Industrial transfer study in economic geography: Progress and prospect. *Economic Geography*, 2014, 34(1): 1-6. (in Chinese)
2. Wei W, Bi C. Environment regulation, interregional industry transfers and pollution heaven effect in China—Empirical analysis based on provincial Panel Poisson Model. *Journal of Shanxi University of Finance and Economics*, 2011, 33(8): 69-75. (in Chinese)
3. Xia Y F. Study on current situation, consequences and countermeasures of foreign investment in China' s pollution-intensive industries. *Journal of Management World*, 1999, (3): 109-123. (in Chinese)
4. Liang Y T, Fan J, Sun W, et al. Study on the comprehensive evaluation

of industrial park development in Guangxi Xijiang Economic Belt. *Geographical Research*, 2011, 30(2): 324-334. (in Chinese)
5. Dong K, Bai B. Pollution heaven effect of regional industry transfer in China. *China Population, Resources and Environment*, 2015, 25(S2): 46-50. (in Chinese)
6. Liu N N, Sun Y H, Tang J H, et al. The environmental effects of pollution-intensive industry agglomeration based on the perspective spatial spillover. *Acta Scientiae Circumstantiae*, 2019, 39(7): 2442-2454. (in Chinese)
7. Zhou H, Zheng Y. The impact of environmental regulation on industry transfer: Evidence from new manufacturing location. *South China Journal of Economics*, 2015, 33(4): 12-26. (in Chinese)
8. Lu M, Feng H. Agglomeration and emission reduction: An empirical study on the influence of urban size gap on industrial pollution intensity. *The Journal of World Economy*, 2014, 37(7): 86-114. (in Chinese)
9. Li Y G, Zhang P. Have industrial agglomeration aggravated regional environmental pollution—Chinese provincial level empirical evidence. *Journal of Huazhong University of Science and Technology (Social Science Edition)*, 2013, 27(5): 97-106. (in Chinese)
10. Kyriakopoulou E, Xepapadeas A. Environmental policy, first nature advantage and the emergence of economic clusters. *Regional Science and Urban Economics*, 2013, 43(1): 101-116.

Appendices: Supplementary Data Tables

Supplementary Table 1 Industrial economic data and non-heavy polluting industry categories

Industrial Economic Category	Heavy Polluting Industry?	Notes
Tobacco manufacturing	No	Formerly "tobacco processing industry"
Printing and recording media reproduction	No	First surveyed in 2012

Industrial Economic Category	Heavy Polluting Industry?	Notes
Cultural, educational, arts, sports, and entertainment goods manufacturing	No	Formerly "general machinery manufacturing"
General equipment manufacturing	No	First surveyed in 2012
Special equipment manufacturing	No	-
Automotive manufacturing	No	-
Railway, ship, aerospace, and other transportation equipment manufacturing	No	-
Electrical machinery and equipment manufacturing	No	-
Computer, communication, and other electronic equipment manufacturing	No	-
Instrument and meter manufacturing	No	-
Other manufacturing	No	-
Waste resource comprehensive utilization	No	-
Metal products, machinery, and equipment repair	No	-

Note: Statistical caliber is total industrial output value (100 million yuan RMB). In 2012, the statistical standard changed from "total industrial output value" to "industrial sales output value." The statistical caliber for 2019 is "total assets."

Supplementary Table 2 Industrial economic data and heavy polluting industry categories

Industrial Economic Category	Heavy Polluting Industry?	Notes
(Mining)	Yes	-

Industrial Economic Category	Heavy Polluting Industry?	Notes
Coal mining and washing	Yes	Formerly "food processing industry"
Petroleum and natural gas extraction	Yes	Formerly "beverage manufacturing"
Ferrous metal mining	Yes	Formerly "textile, apparel, footwear manufacturing"
Non-ferrous metal mining	Yes	First surveyed in 2012
Non-metallic mineral mining	Yes	-
Mining support activities	Yes	-
Other mining	Yes	-
Agricultural and sideline food processing	Yes	Formerly "petroleum processing and coking industry"
Food manufacturing	Yes	First surveyed in 2012
Alcohol, beverage, and refined tea manufacturing	Yes	-
Textile, apparel, and accessories manufacturing	Yes	-
Leather, fur, feather products and footwear manufacturing	Yes	-

Industrial Economic Category	Heavy Polluting Industry?	Notes
Wood processing and wood, bamboo, rattan, palm, straw products	Yes	-
Furniture manufacturing	Yes	-
Papermaking and paper products	Yes	-
Petroleum, coal, and other fuel processing	Yes	-
Chemical raw materials and chemical products manufacturing	Yes	-
Pharmaceutical manufacturing	Yes	-
Chemical fiber manufacturing	Yes	-
Rubber and plastic products manufacturing	Yes	-
Non-metallic mineral products manufacturing	Yes	-
Ferrous metal smelting and pressing	Yes	-
Non-ferrous metal smelting and pressing	Yes	-
Metal products manufacturing	Yes	-
Electricity, heat production and supply	Yes	Formerly "electricity, steam, hot water production and supply"
Gas production and supply	Yes	-
Water production and supply	Yes	-

Note: Statistical caliber is total industrial output value (100 million yuan RMB). In 2012, the statistical standard changed from "total industrial output value" to "industrial sales output value." The statistical caliber for 2019 is "total assets."

Supplementary Table 3 Descriptive statistics of provincial data

Variables listed: Heavy polluting industry output, total industrial wastewater discharge, chemical oxygen demand in industrial wastewater, total industrial waste gas emissions, industrial sulfur dioxide emissions, industrial smoke and dust emissions, industrial solid waste generation, industrial solid waste discharge, industrial pollution control investment, per capita GDP, secondary industry share

of GDP, secondary industry total value, R&D expenditure, patent grants, average urban wage, foreign direct investment.

Note: Figure translations are in progress. See original paper for figures.